Space Weather Technical Forecast

Issued on Sunday, 17 December 2023 at 00:43 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: G1-G2 Likely in current UTC day in a generally disturbed four-day forecast period. Risk of further R2 and S1 now moderating slightly.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity reverted to Low over the past 24 hours, with X-ray activity recorded at GOES16 and 18 showing only C-class flares, peaking with a long-period C8.3 from AR3514 at 16/1434UTC.

There were eight sunspot regions on the disc at the end of the UTC day of Saturday 16 December, however this number was slightly volatile over the period as a whole given a number of new unipolar regions, mainly in the eastern solar hemisphere. The most notable activity in the current cohort was again from the large and complex AR3514, although this group became difficult to fully discern near the southwestern limb, but remains at least an Esc/Beta-Gamma, with its growth trend apparently stable. Also of note were AR3520, which saw a new trailer emerge in the period, and also AR3519, which underwent minor spot proliferation as it approached the solar meridian.

As mentioned in previous issues of this guidance, a filament eruption that occurred shortly prior to the start of this past 24-hour window at 15/2100UTC has now potentially been accounted for as a very faint CME seen heading south in Lasco C2 and very tenuously in STEREO A COR2. The MOSWOC Enlil model suggests arrival early in the UTC day of Wednesday 20 December as most probable.

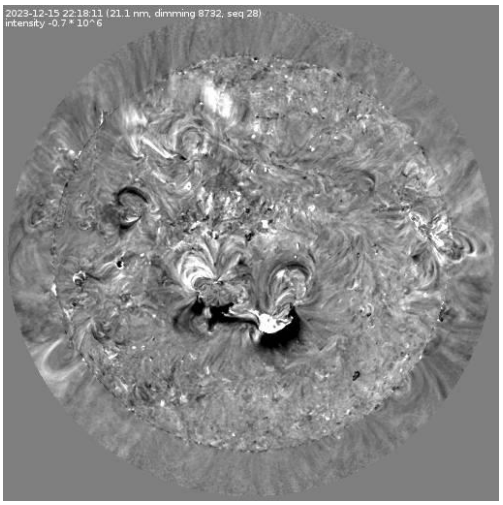

Figure 0: SIDC ROB-processed AIA211 time-integrated dimming of the 15/2100UTC south central filament eruption. This feature has tentatively been associated with weak ejecta heading mainly south of the Sun-Earth line, but with a provisional glance of Earth possible early in the UTC day of Wednesday 20 December.

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Other activity noted in the period included a prominence eruption from the southeastern limb at 16/1100UTC, and a CME tied to the C8.3 from AR3514 at 16/1434UTC. The former plays no part in the forecast, and the latter is awaiting analysis but similar is assumed given its far westward emission location.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by ACE and DSCOVR at L1, were initially reflective of waning effects from a weak CME arrival at 15/1057UTC. This had possibly ceased by the UTC evening, with a stable, slightly elevated trace then taking over.

The solar wind speed peaked near 525km/s during the early hours UTC in the throes of the CME, later gradually waning to finish the 24 hours nearer 425. The solar wind density was Slightly Elevated but steady over the same timeframe, with a range between 10 and 20ppcc. The IMF was somewhat erratic in character, with an early peak to 11nT, while the north-south component ranged between +8 and -7nT. The phi angle was mainly positive (away from the Sun), with a brief flit into negative around 15UTC perhaps signaling the tail of the CME's influence.

The net result of the above solar wind measures was for provisionally Quiet to Active geomagnetic activity, with a peak Kp of 4- seen in the 00-03UTC interval while the CME's effects were strongest.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux fell from an early peak of S1 and 13pfu at 16/0015UTC, with this having been in response to the recent larger flares from AR3514. It has since dropped near resting background below 1pfu, with higher energies unmoved throughout.

GOES16 high energy (greater than 2MeV) electron flux was mostly at Normal Background levels, with a brief low Moderate peak in the UTC afternoon. The 24-hour fluence was well below the Active threshold (1e8 integrated pfu). The observation at 17/0001UTC was 2.56e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: There remains a Chance of further Moderate activity and a Slight Chance of Strong, both largely tied to the fortunes of AR3514, which is due to rotate off the disc into the new UTC working week. While some further active regions are likely over the eastern solar horizon, these are unlikely to fully compensate, and there is a step-wise moderating risk of significant flares as a result.

Solar Wind / Geomagnetic Activity: There are up to three CMEs that now feature in the forecast. The X2.8 flare from AR3514 on 14 December produced a moderately fast CME which is likely to have an Earth-directed component due within the next 24 hours, i.e. the UTC day of Sunday 17 December. This is thought likely to have swept up an earlier high coronal filament from the northwest disc, also from 14 December. Finally, there is further weak influence from the 15/2100UTC south-centre disc filament due in the UTC morning of 20 December.

The coronal hole-driven forecast is simpler, with CH79 now not expected to feature. This only leaves the more assured CH82/+ as due on day three, Tuesday 19 December.

Initially Quiet geomagnetic activity is Likely to give way to Minor or Moderate (G1/G2) geomagnetic storms inside the first 24 hours with the combined arrival of the 14 December CMEs. Activity should then wane for a time into the new working week, ahead of CH82's fast wind, which may reach Elevated levels. Rounding out the forecast is then a weaker 15 December filament CME early in the UTC day of 20 December.

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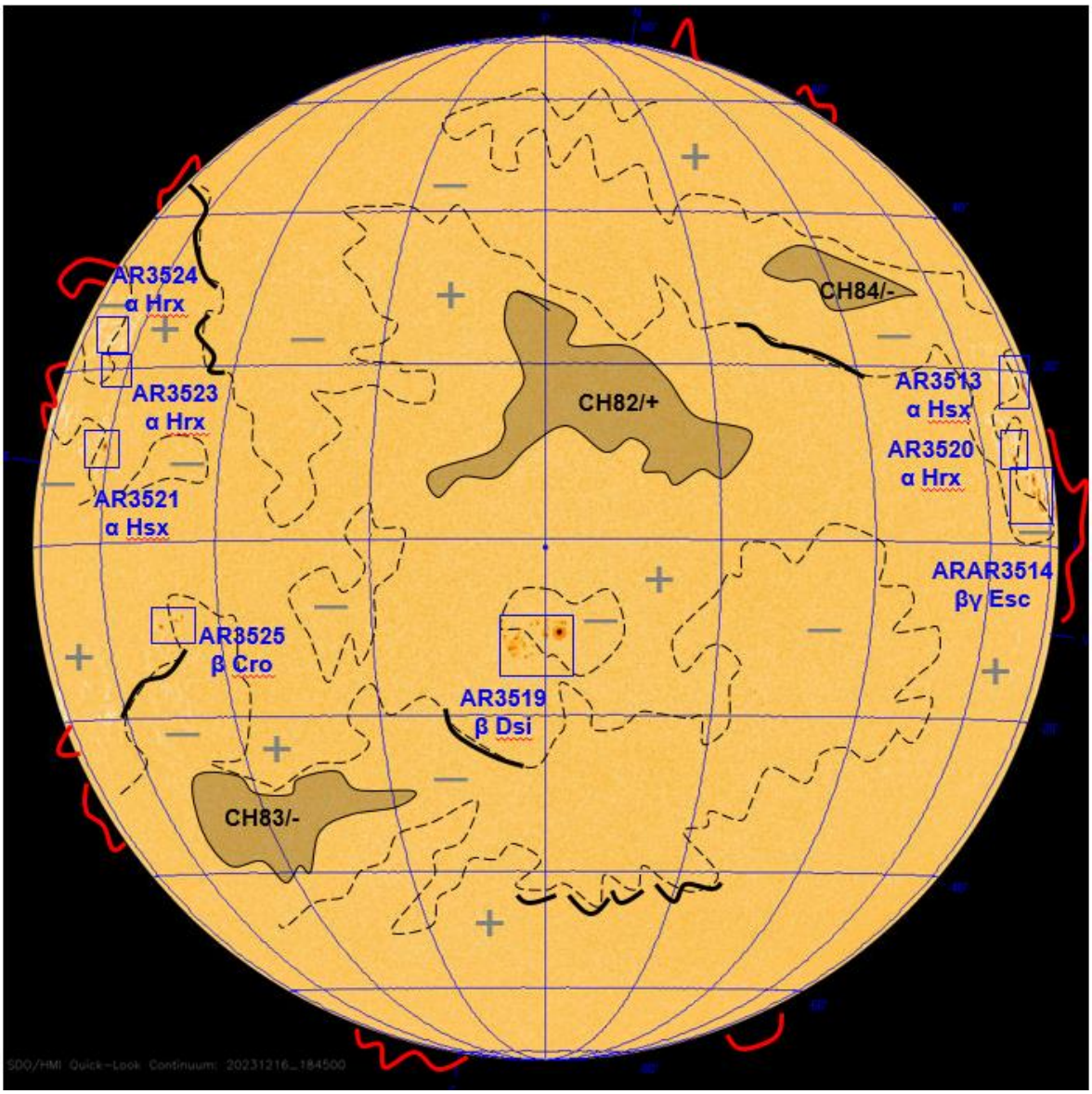
Energetic Particles / Solar Radiation: GOES16 high energy proton flux remains slightly elevated, and as such the chances of further S1 conditions are above raw values for the constituent sunspot regions on the disc, rated a Chance over the remainder of the current UTC weekend should AR3514 flare appropriately again, and waning from here as the sunspot group rotates onto the far side. Forecast CME arrivals during this time may also help to increase proton levels.

Regarding high energy electron flux, CME arrivals are likely to keep these in check at GEO initially, with a brief window then arising before further attenuation by CH82/+. The associated 24-hour electron fluence should therefore mostly remain near current levels, with any more appreciable rise probably delayed until after midweek UTC.

Figure 1. Solar Analysis Valid 16/1845UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:
Relative to earlier guidance, any contribution from CH79 and the CME stated as due on 16 December have now been removed - the former now no longer thought likely to occur, and the latter perhaps the cause of the very early CME enhancement on 15 December.

There are therefore up to three CMEs that now feature in the forecast. The X2.8 flare from AR3514 on 14 December produced a moderately fast CME which is likely to have an Earth-directed component due within the next 24 hours, i.e. the UTC day of Sunday 17 December. This is thought likely to have swept up an earlier high coronal filament from the northwest disc, also from 14 December. Finally, there is further weak influence from the 15/2100UTC south-centre disc filament due in the UTC morning of 20 December.

The coronal hole-driven forecast is simpler, with CH79 now not expected to feature. This only leaves the more assured CH82/+ as due on day three, 19 December.

The latest MOSWOC Enlil run and ensemble is highly disturbed for much of the coming four-day period given the number of transients and fast winds that feature. The 14 December CMEs are likely to arrive as a united front if present, and should give the peak geomagnetic activity for the period, with G1/G2 Likely, even though much of the ejecta was produced ahead of the track of the Earth in its orbit. Neither ACE EPAM LEMS and STEREO A MAG and PLASTIC currently show any signs of imminent arrival, with STEREO likely to see a more direct impact given that it is 7 degrees upwind and nearer the X-class emission longitude.

The onset of CH82 is of moderate confidence, as although a persistent feature, it has had a history of a westward pointing promontory that may produce a slightly earlier onset, although this now appears to have closed. Even though we are very near the minimally geoeffective solstice, the intensity of the coronal hole and its history of having produced a G1 on last pass lend themselves to a further Chance of similar on 19 December.

Finally, the south-centre disc filament from 15/2100UTC has recently been analysed using scant, faint coronagraph imagery. Given its central position, Earth impacts are considered fairly likely but probably muted for being slow and weak - assuming the correct CME front has been identified and the ejecta were not otherwise reabsorbed.

All in, the coming four days are likely to be relatively disturbed in terms of geomagnetism, with windows of more favourable conditions generally short-lived and of low confidence -probably most reliably present in the immediate term and separating the 14 December CMEs and CH82, i.e. perhaps later Monday and early Tuesday 19 December.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	70	20	30	20
Strong	G3	No	20	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

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Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
14/2112	Full	X2.8 from AR3514	NW	974km/s	Early UTC day 17 December	Amalgamated with NW filament from same UTC day. Low confidence in timing
16/1947	Partial	Filament	S Centre	341km/s	Early UTC day 20 December	Uncertain attribution of faint CME, low confidence

Figure 2: Latest MOSWOC Enlil run and ensemble (17/1800UTC badge time), paused at time of 15 December south-central filament crossing 1AU (rightmost magenta boxes on each image). Also shown are the combined 14 December CMEs (also boxed magenta), and the now-passed CME that perhaps arrived 24 hours early on 15 December (grey).

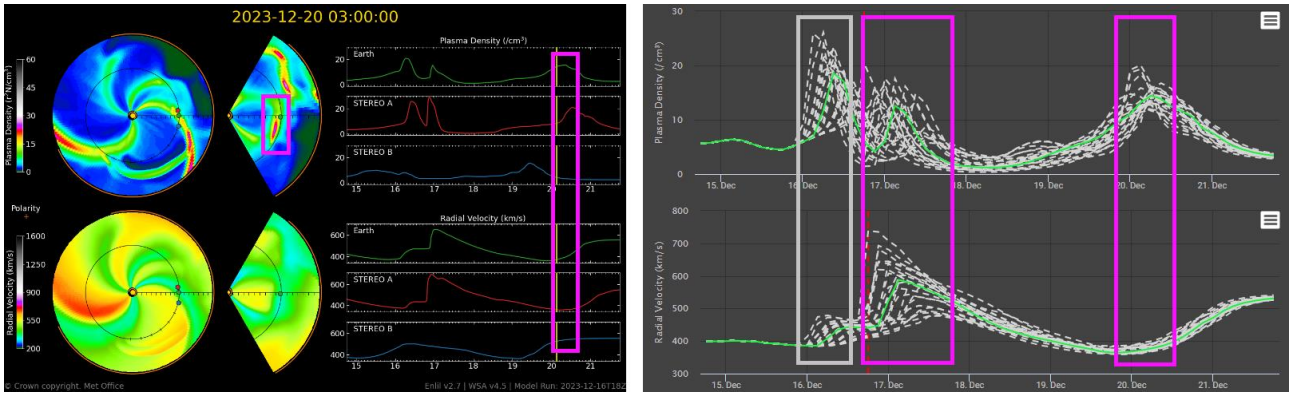

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Figure 3: CAT tool analysis of 15/2100UTC south-central filament, showing very faint ejecta forming western part of cone on C2, perhaps also on STEREO A COR2.

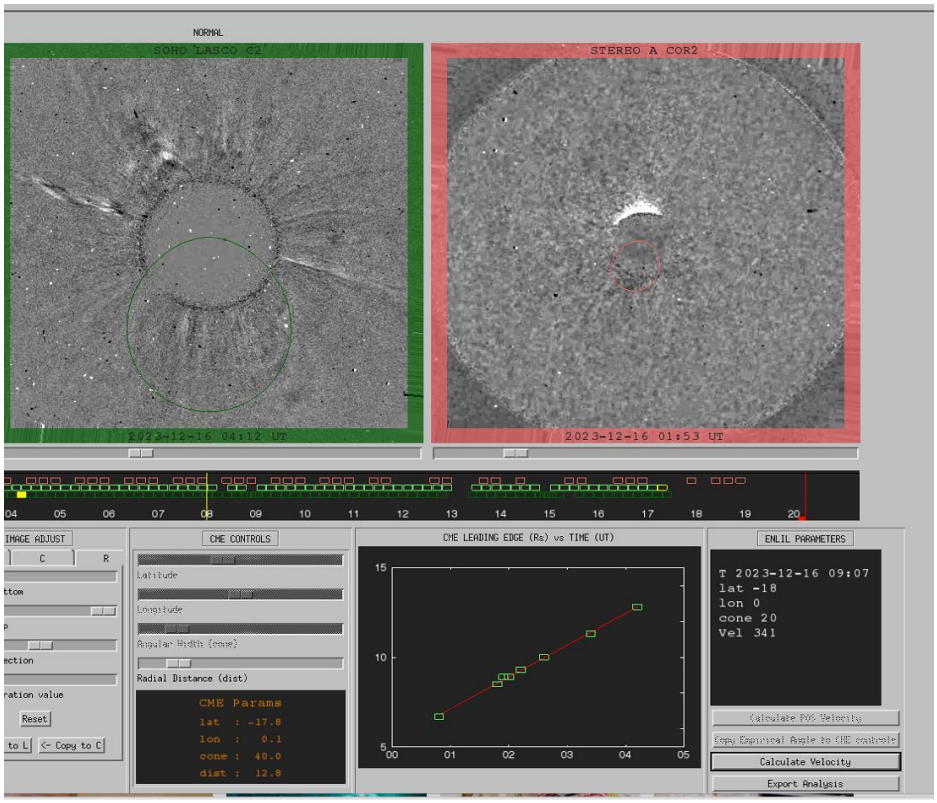
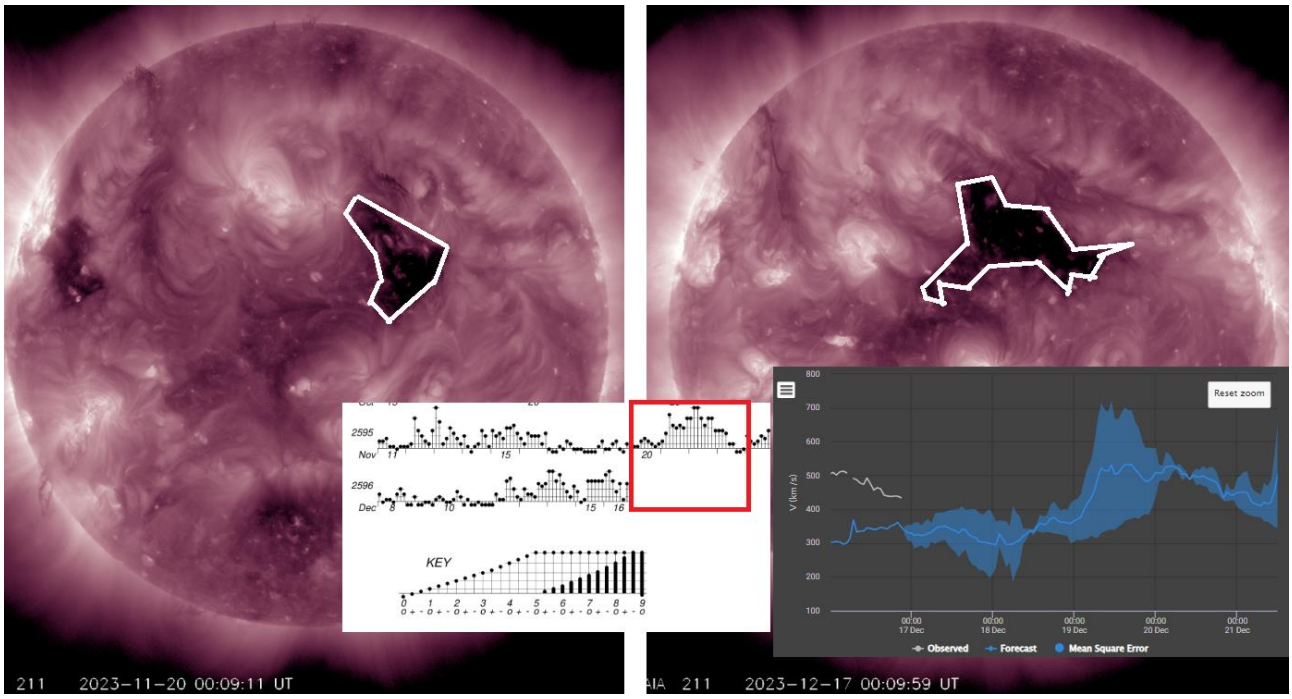


Figure 4: AIA211 from previous and current rotations, with CH82 and its predecessor delineated. Also shown is resulting geomagnetic activity, which peaked at G1, and the past fast wind, which can be seen to have reached about 500km/s. The western fringe of CH82 in its current guise stretches a way beyond the main body of the coronal hole, and muddies the likely onset a little, although this is still felt most likely to be within the UTC day of Tuesday 19 December.



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Radio Blackouts - X-Ray Flares:

The current X-ray forecast is highly dependent on the fortunes of AR3514, with the current daily risk notably higher than the raw disc would otherwise suggest given observed activity in the main sunspot group, although this has been mollified a little as observed activity has fallen. Discerning the current character of the sunspot group is now difficult given the narrowing viewing angle, however it appears to at least constitute an Esc/Beta-Gamma. This feature is expected to cross onto the far side of the Sun during the UTC day of Monday 18 December, and as such there is a step-wise transition downward in the chances of further significant flares. This is despite the returning Carrington locations of many sunspot regions over the eastern solar horizon, mainly earlier in the period, as far side soundings and limb EUV flux here are not readily backed up by CME and dimming evidence from the oncoming far side to suggest anything comparable making up for the loss of by then Ex-3514.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	No	50	45	40	40
Very Active	R3 to R5 X Class	No	15	10	1	1

Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 peaked at 13pfu early in the past 24 hours in response to activity from AR3514. The observed spectra were relatively soft, with 50 and 100MeV protons unmoved, despite the westward emission location from the X and M-class flares. The breach of S1 was not seen at GOES18 in otherwise very similar spectra, perhaps implying a local effect for GOES16.

Flux levels are still slightly elevated, and as such there is a slightly increased risk of further breaches of S1 in the next 24 hours or so, exacerbated by the incoming twin 14 December CMEs. The risk of S1 should then relax: with CME effects waning, residual GOES16 proton counts naturally ebbing, and also as the region responsible for much of the risk departs the Earth-facing side into the new UTC working week.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	≥ S1	Yes	30	15	10	10
Very Active	≥ S3 *	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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Figure 4: Past 72 hours in high energy proton flux, showing causative X-ray flares at GOES16 (lowest plot) and resultant flux at GOES 16 and 18 – note that only GOES16 saw exceedance of S1, and that there is a periodic slight enhancement around UTC midnight bookending the past 24 hours.

High Energy Electrons Event (≥ 2MeV):

High energy electron flux is currently mainly within Normal Background levels, and is expected to remain so in the immediate term. The combined 14 December CMEs are likely to compress the Van Allen belts as and when they pass Earth, however there is then a window for recovery between the CME effects waning and the fast wind from CH82 arriving. This leads to a peak Slight Chance of Active 24-hour integrated fluence on Tuesday 19 December before the coronal hole arrives, with any more assured rise probably then delayed until later in the coming UTC working week as CH82 wanes.

GEO Electron Environment	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	5	20	10
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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